METHODS FOR ENCODING DATA IN AN ANALOG VIDEO SIGNAL SUCH THAT IT SURVIVES RESOLUTION CONVERSION

RELATED APPLICATIONS: This application claims the benefit of United States Provisional application Nos. 60/445,660 filed on February 7, 2003, 60/446,726 filed on February 11, 2003, and 60/460,928 filed on April 7,2003.

BACKGROUND

A. FIELD OF INVENTION

This invention pertains to a method and apparatus for imbedding control signals in the visible portion of a video signal.

B. DESCRIPTION OF THE PRIOR ART

United States Patent No. 4,807,031 in the name of Broughton, et al. that issued on February 21, 1989 and is entitled "Interactive Video Method and Apparatus" discloses a method and apparatus for in-band, video broadcasting of commands to interactive devices. Control data is encoded into the video image using a "subliminal" modulation scheme, a scheme that can be detected electronically but is largely imperceptible to the viewer. The encoding is in a selected sequence of video image fields. The resulting modulated video fields are within the displayed area of the video (the area that is seen by the viewer), and have alternately proportionately raised and lowered luminance on selected horizontal scan lines. As disclosed in the patent, the modulation is monitored by a light sensitive device positioned adjacent the user's television screen.

The modulation of the video signal used by Broughton, et al. is referred to herein as "VEIL modulation", VEIL being the commercial name of the system based on the patent. VEIL is simpler and easier to implement than watermarking technology in that the VEIL modulation can be sensed by looking for a single frequency in the video signal.

VEIL has been proven to work in standard definition television systems such as 525-line, 60 Hz interlaced (NTSC) and 625-line, 50 Hz interlaced

(PAL). However, the introduction of new television systems such as the Advanced Television System Committee's Digital TV Standards which includes digital high definition television (HDTV), standard definition television (SDTV), data broadcasting, multi-channel surround-sound audio, and satellite direct-to-home broadcasting means that in the future video signals will be subjected to changes in resolution between the point of transmission and the display device.

The ATSC standard includes the standard definition resolutions such as 525i (the NTSC signal, 525 lines transmitted as an interlaced signal), and high definition resolutions such as 720p (720 lines transmitted as a progressive scan signal) and 1080i (1080 lines transmitted as an interlaced signal). Changing the resolution of a video signal is commonly referred to as "up res'ing" when the resolution of the video signal is increased and "down res'ing" when the resolution of the video signal is decreased.

VEIL encoding involves increasing the average luminance of one line in a field and decreasing the average luminance of the next adjacent line. There is no problem when up res'ing as will be explained below. However, if the video signal with the VEIL encoding is subjected to down res'ing, the VEIL encoded data may not be retrievable.

It is a general object of our invention to provide a form of VEIL modulation that can be detected even after down res'ing.

It is another object of our invention to provide VEIL modulation detection with the same notch filter and level detector no matter how the resolution is changed.

SUMMARY OF THE INVENTION

VEIL encoding can be detected using a notch filter centered at half the line frequency. The basic technique of the invention is to implement VEIL encoding by coding groups of lines, not alternate lines. This allows detection with a notch filter even after subsequent down res'ing.

The theory of the invention can be appreciated by considering, for example, that alternate pairs of lines of video are given increased luminance, and alternate pairs of lines are given decreased luminance. A complete cycle takes four lines. If the video signal is subjected to down res'ing, then half the lines are lost. A complete cycle of the VEIL modulation now occurs in only two lines. But in order for

the frame rate to remain the same, the line sweeps of the signal with lower resolution (half the lines) have to be slowed down by half in order for it to take the same time to sweep out a complete frame. This, in turn, means that it takes the same time to detect one complete cycle (higher luminance followed by lower luminance) in both signals so the same notch filter can be used to detect the modulation. (In this case, the notch filter has to be at one-quarter the line frequency, rather than one-half as in the Broughton, et. al patent, because a complete cycle in the original signal prior to a change in resolution now takes four lines instead of only two.)

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects, features and advantages of the invention will become apparent upon consideration of the following detailed description in conjunction with the drawing, in which:

Fig. 1 depicts up res'ing of a signal;

Fig. 2 depicts down res'ing of a signal;

Figs. 3 and 4 show alternative coding methods that allow the same notch filter to detect VEIL encoding whether or not there has been down res'ing;

Fig. 5 shows a circuit for detecting VEIL encoded data in a video signal; and

Fig. 6 shows a circuit for removing VEIL encoded data from a video signal.

DETAILED DESCRIPTION

In each of Figs. 1-4, waveform (A) represents the original or source video signal with VEIL encoding. Waveforms (B) and (C) represent respective signals after a resolution change. In each waveform, the horizontal axis is time and the vertical axis is luminance. Each horizontal scan line is represented as a period of zero luminance which is the horizontal blanking interval followed by a longer period of with a positive luminance. The luminance is shown as constant during the horizontal line which is of course a simplification of a real video signal where the luminance might fluctuate along each line. The solid zigzag line represents the output of the filter labeled X in the VEIL detection system shown in Fig. 5.

Fig. 1 shows how with up-res'ing the VEIL encoded data in an original video signal is still detectable. The original signal of Fig. 1(A) is shown with twice the resolution in Fig. 1(B). Fig. 3(B) shows the signal with an interpolated increase in resolution of three times the original. With any of the three different resolutions of Fig. 1, the VEIL encoded data remains detectable using a notch filter centered on 1/2 f_{hl} where f_{hl} is the horizontal line frequency of the original video. Doubling the number of lines, for example, requires that each of them be swept across the screen in half the time, in order to leave the frame rate unchanged. But this means that it takes the same time to detect the same number of lines. So the same notch filter can be used for the up res'd signal.

In Fig. 2(A), the VEIL encoding of the data has been applied to a video signal that does not have the lowest possible resolution. The signal might be, for example, a 720p HDTV signal. Fig. 2(B) represents a 525i standard definition signal. As in the case of Fig. 1, the VEIL encoded data in the original signal can be detected using a notch filter centered on f_{hl}, the horizontal line frequency of the original video. However, if the signal is subject to a decrease in resolution as shown in Fig. 2(B), the VEIL encoding is now more difficult to detect. Detection requires a notch filter centered on 1/2 $f_{hl,}$ where f_{hl} is the horizontal line frequency of the new video of Fig. 2(B) and a more sensitive circuit is required since the amplitude of the VEIL modulation is reduced.

Figs. 3 and 4 show alternative methods of encoding the data in a way that is very similar to VEIL but allow the coding to be detected by the same notch filter and level detector regardless of any decrease in the resolution of the video signal.

In this method, the data is encoded by modifying the average luminance of N adjacent lines in a field, where N is twice the reduction in video resolution that the encoding is required to survive. (If no change in resolution is required, then N is 2 and the coding method is VEIL.)

In Fig. 3, the data is encoded in such a way that that the encoding will survive a reduction in resolution by a factor of 4 from the original video signal in Fig. 3(A) to the quarter resolution video in Fig. 3(C). In this case, the encoding involves 8 adjacent lines (N=8, since N is twice the 4-fold reduction in video resolution).

However, simply applying the VEIL algorithm across all N lines by increasing the luminance on the first N/2 adjacent lines, e.g., by 10%, and then

reducing the luminance on the next N/2 adjacent lines by the same amount will not be satisfactory since the encoding is unlikely to remain subliminal. (The value of 10% is chosen for example only; the actual value used will depend on different design considerations such as the ability of the detection circuitry to detect lower values of luminance variation.)

In Fig. 3(A), the luminance level on each of the lines is controlled by a sinusoidal function with a full period of 8 lines that boosts and reduces the average horizontal luminance by up to 10%. The gain applied to each line by such a function is approximately as follows:

Line	Percentage Change
1	6
2	10
3	9
4	3
5	-3
6	-9
7	-10
8	-6

In Fig. 4(A), the data is encoded using a sawtooth function to control the change in average luminance in each of the N lines. Here, the gain applied to each line by such a function is approximately as follows:

Line	Percentage Change
1	2.5
2	5
3	7.5
4	10
5	-10
6	-7.5

7	-5
8	-2.5

The two tables just considered reveal an important feature of the invention. While in Broughton, et. al alternate lines have their luminances changed in opposite directions, in our invention the luminances of the lines are changed in such a way that most of the lines are adjacent other lines whose luminances are changed in the same direction. In fact, in each table, every line is adjacent at least one other line whose luminance is changed in the same direction, and only two of the lines are adjacent others whose luminances are changed in the opposite direction.

In summary, the method of encoding data into the video signal such that it survives a reduction in resolution in the video signal is to encode it across N lines where N is twice the ratio between the original resolution of the image and the lowest resolution at which the encoding must still be detectable. Thus, if the highest resolution to be accommodated is 1080i and the lowest resolution is 525i, then N is 4 (the ratio of the number of lines in 1080i to those in 525i is approximately 2).

No matter what the change in resolution, and whether it is up or down, the center frequency of the notch filter in the detection system can be set to a constant which is half of the horizontal line frequency of the lowest resolution video signal in the range of video signals to be accommodated. For example, if the lowest resolution video signal to be accommodated is NTSC, then the notch filter center frequency is set to 1/2 f_{hl} on all detectors where f_{hl} is the NTSC horizontal line frequency.

When a video signal is converted from an interlaced scan to a progressive scan and vice versa, there is an increase or decreases in resolution similar to that described above. For example, if a 525 line progressive scan video signal is converted to a 525 line interlaced video signal, then the 525 line frame becomes two fields with 262.5 lines each. For VEIL encoding it is adjacent lines in the same field that matter, and therefore this conversion has the same effect on VEIL encoding as halving the resolution. The converse is also true, for example, going from a 525 interlaced video signal to a 525 line progressive scan video signal is akin to doubling the resolution.

The circuit of Fig. 5 shows how VEIL modulation can be detected as suggested by Broughton, et al, where the detection is designed, as discussed above,

to detect a frequency occurring at one-half the lowest line frequency of the range of video signals to be accommodated. All that is required to detect the frequency is a high-Q Band Pass filter 10, as shown in Fig. 5, to isolate the VEIL frequency. It is then rectified and tested against a comparator threshold in the signal shaper circuitry 12. The final decode of the signal, such as determining whether the VEIL encoding is present in one line and not in the next takes place in the decode logic 16.

In certain cases it may be desirable to remove data encoded into a video signal using VEIL or a similar encoding scheme. For example, someone attempting to circumvent content protection signaling that used VEIL encoding might attempt to remove the VEIL encoded content protection. Fig. 6 shows a block diagram of such a removal device. This particular implementation operates on an S-video signal, but one skilled in the art can construct a device to remove the encoding from a component video signal or a device to remove the encoding from a composite video signal.

In Fig. 6, the luminance signal of the incoming video from which it is desired to remove the VEIL encoded data is split between a delay line that incorporates a line store 22 capable of storing a certain number of lines and a VEIL encoding detection circuit 24 that is largely the same as circuit 14 of Fig. 5. The length of the delay is adjusted such that the first line in a VEIL encoded pattern exits the line store delay line at the same moment that the output of the VEIL detector signals VEIL is present. A second delay line 20 operates in parallel providing the same delay to the chroma signal so that the two parts of the S-video signal are not out of phase when they are output from the circuit at 26.

The output of the detector triggers a function generator 28 that generates a waveform that is the inverse of the VEIL encoding scheme. This waveform is fed into a voltage controlled amplifier which changes the average luminance of the lines being clocked out of the line store delay line. For example, in standard VEIL encoding the average is raised by 10% on the first of two field adjacent lines and lowered by 10% on the second of two field adjacent lines. In this case the function generator output would cause the voltage controlled amplifier to decrease its gain to 0.9 (10% down from unity) for the first line and increase its gain to 1.1 (10% up from unity) for the second line. For the remaining lines where VEIL encoding is not detected the gain is unity. If more complex encoding schemes are

used as described above, then the function generator generates a complementary waveform

Although the invention has been described with reference to a particular embodiment, it is to be understood that this embodiment is merely illustrative of the application of the principles of the invention. Numerous modifications may be made therein and other arrangements may be devised without departing from the spirit and scope of the invention.